A NOVEL CONCEPT FOR REDUCING WATER USAGE AND INCREASING EFFICIENCY IN POWER GENERATION

UCR Contractor Review Meeting

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INTRODUCTION

In recent years, gas turbines play an increasingly important role in electric power generation for the utility industry. However, power output from a gas turbine decreases significantly during hot summer months just when more power is needed. Inlet-air cooling can be used to minimize such performance degradation for gas turbines. Specifically, a technology based on ice thermal storage can offer cost effective intake-air cooling to optimize the power output of a gas turbine. In addition, it recovers condensate from the air, which can be used to reduce net water usage for power generation facilities.

OBJECTIVE

The objective of the project is to apply ice thermal storage technology to intake-air cooling to gas turbines used in power plants (including combined cycle plants) in order to increase overall power output, improve efficiency or reduce heat rate, and have additional benefit of reducing the water usage in power generation systems by recovering condensate from humid air.

SCOPE OF WORK

The University of Pittsburgh and the *Weismantel International* have formed a project team to explore the commercial feasibility of applying the ice thermal storage technology to industrial and aeroderivative gas turbines used for power generation. The work includes the following three tasks:

Task #1: *T*heoretical analysis

Task #2: Computer simulation

Task #3: Engineering design & cost analysis

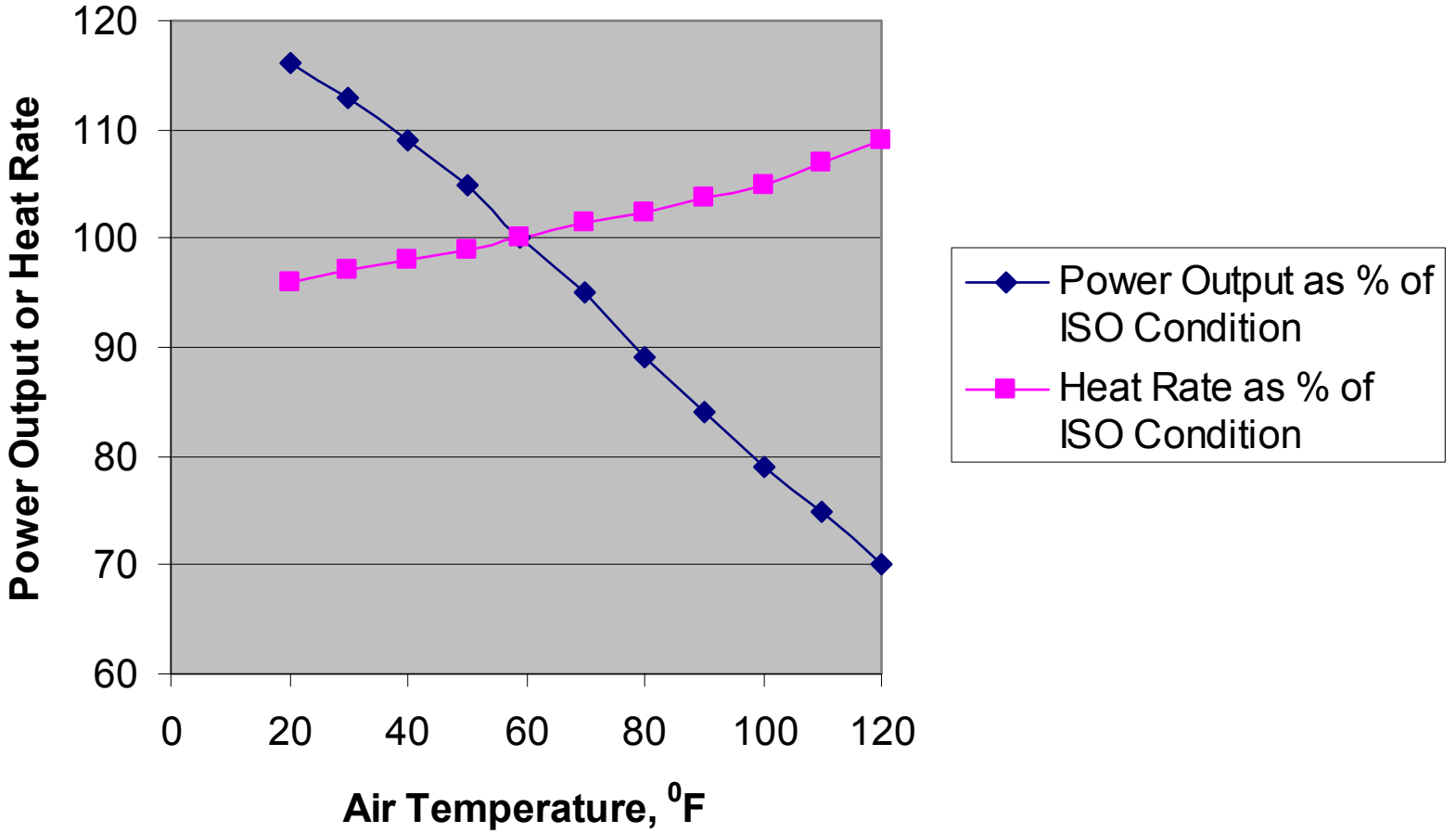
TECHNICAL PROGRESS

Task #1: Theoretical Analysis

Analytical work completed to date includes the following:

1. Established the baseline performance curves for an industrial-grade and an aeroderivative-type gas turbine. Both turbines are rated at 50 Mw at ISO conditions.
2. Assembled an annual record of "Engineering Weather Data," which include dry/wet bulb temperatures, for two selected sites: Phoenix, AZ and Houston, TX.
3. Developed methodology to calculate: (1) the power output and heat rate of gas turbines, and (2) the quantity of recoverable water from air cooling as a function of intake-air temperature based on weather data and specified operating conditions for ice thermal storage cooling system.

Typical gas turbine performance curves
(ISO at 59 ^{0}F)



Sample Engineering Weather Data

Luke Air Force Base / Phoenix, AZ

(Latitude 33 33 N Longitude 112 22 W Elevation 1101 feet)

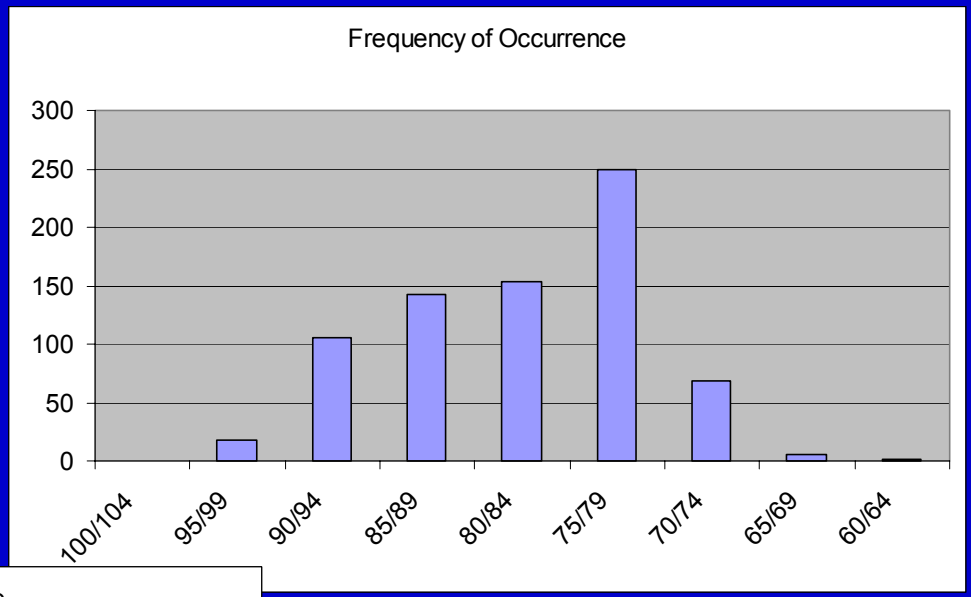
July

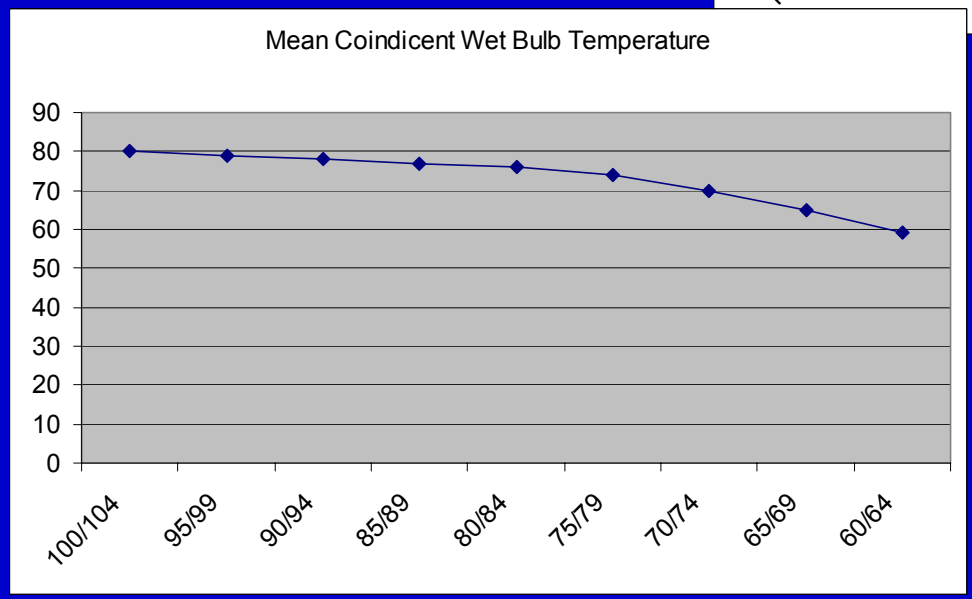
Temperature Range D B, °F	Total Obsn	M C W B °F
115/119	2	73
110/114	16	72
105/109	69	72
100/104	117	71
95/99	119	71
90/94	135	70
85/89	139	66
80/84	96	67
75/79	42	66
70/74	7	60
65/69	1	54
<60/64	no data	no data

Sample Engineering Weather Data

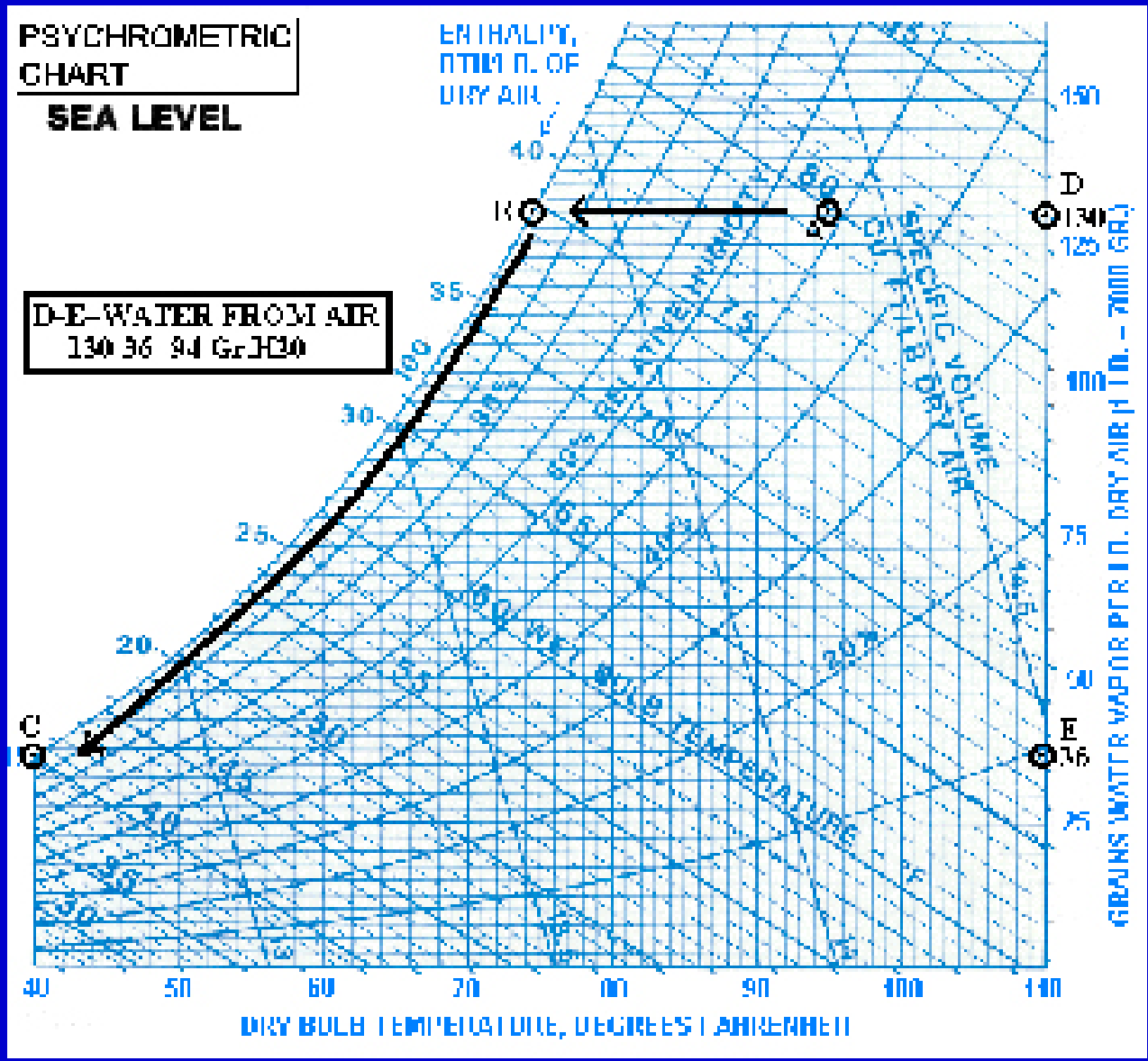
Month of July

Houston, TX





Method for Calculating Water Recovery



Task #2: Computer Simulation

Based on the results of Task #1, computer simulation has been carried out for gas turbines operated at two geographic locations: one in the desert (Phoenix, AZ) and other at a humid, coastal site (Houston, TX). These turbines have a design capacity of 50 Mw. Simulation runs are performed over a one-year period to generate data for both power output (Kw) and heat rate (Btu/Kwh) as well as water recovery (acre feet/year) using the ice thermal storage cooling system.

Input and Output Data

Input Data:

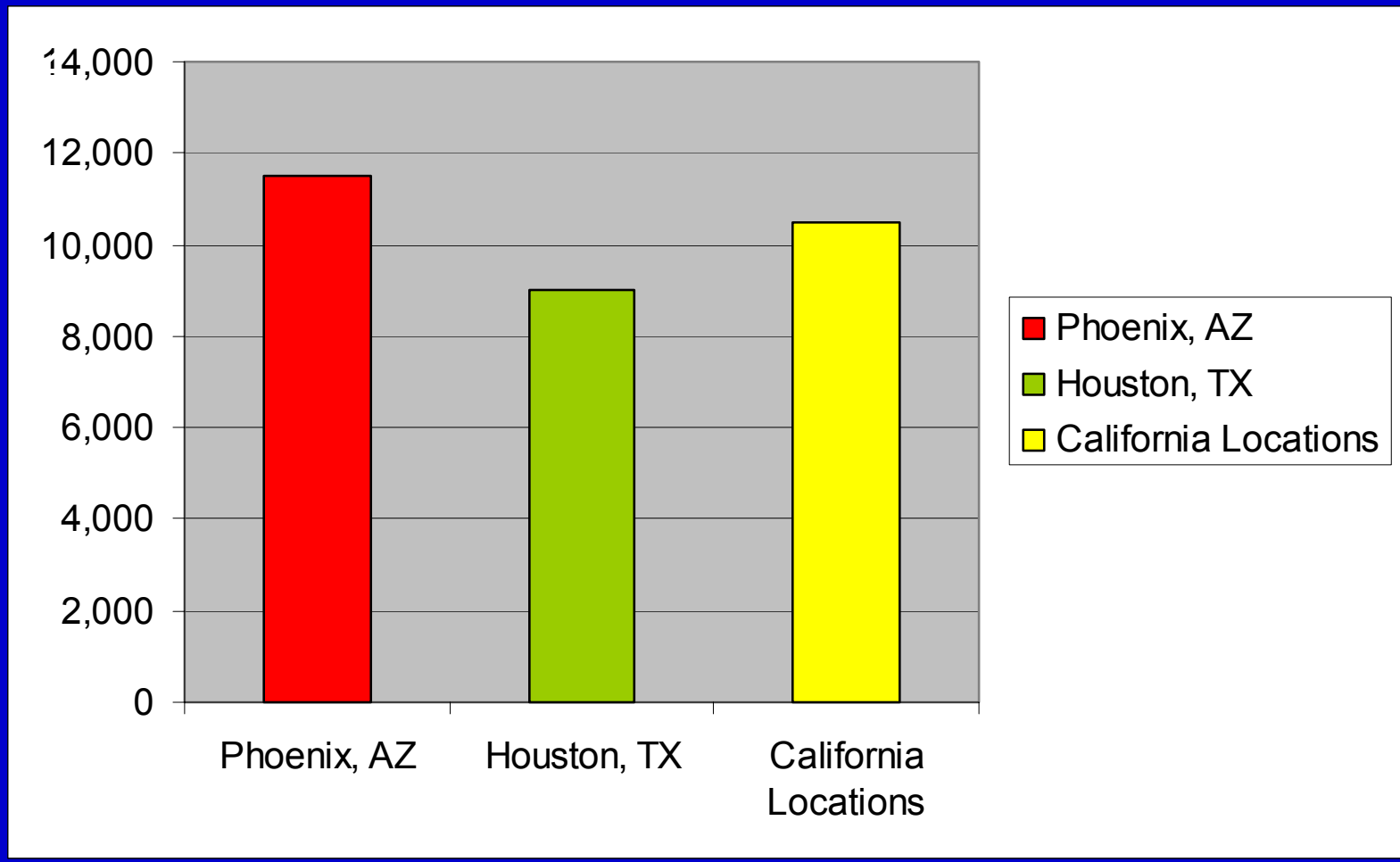
- The detailed weather records for dry/wet bulb temperatures for each location
- The air mass flow rate of the gas turbine compressor
- The desired turbine inlet air dry bulb and wet bulb temperatures
- The number of days the gas turbine generator will operate annually
- The number of off-peak hours each day that are available to build ice
- The number of hours each day when the gas turbine generator's performance is to be augmented

Output Data:

- A daily record of calculated hourly power output (Kw) and heat rate (Btu/Kwh)
- A daily record of calculated power consumption for ice making at off-peak hours
- A daily record of calculated water recovery from intake-air cooling operation

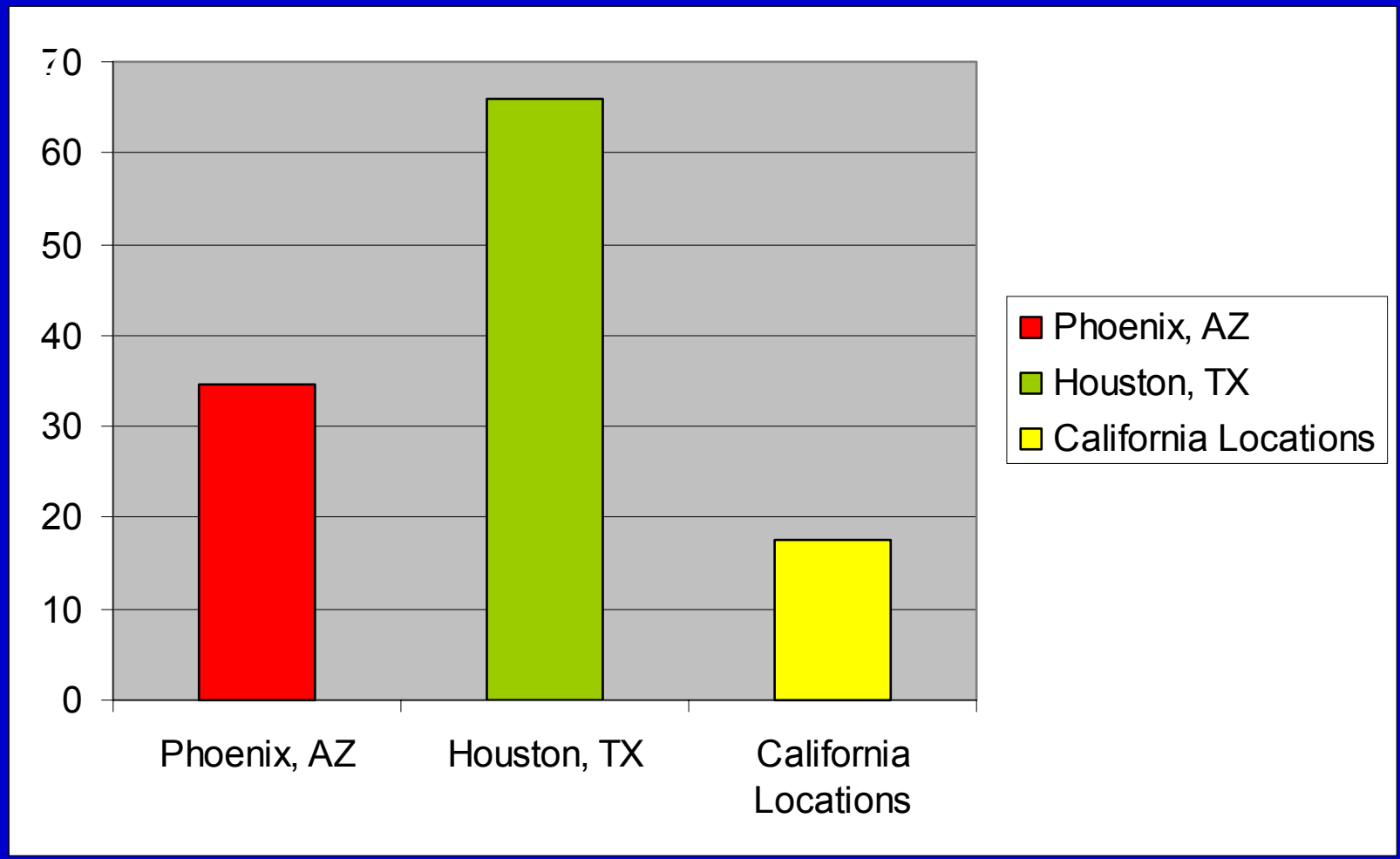
Calculated Gains in Power Output

Net gain in power output in Kw for a 50-Mw turbine



Estimated Annual Water Recovery

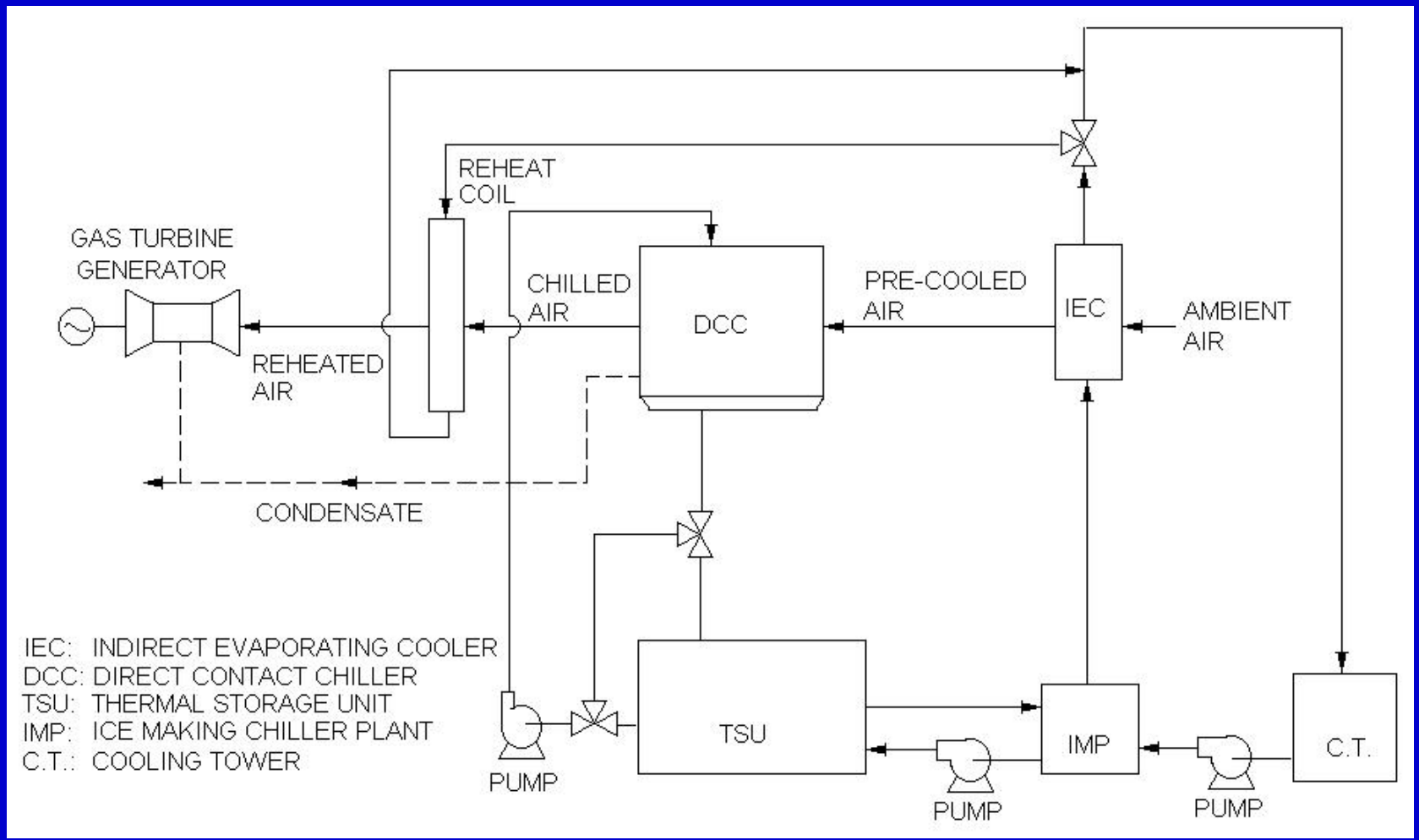
Water recovery from a 50 Mw turbine, in acre-ft/year



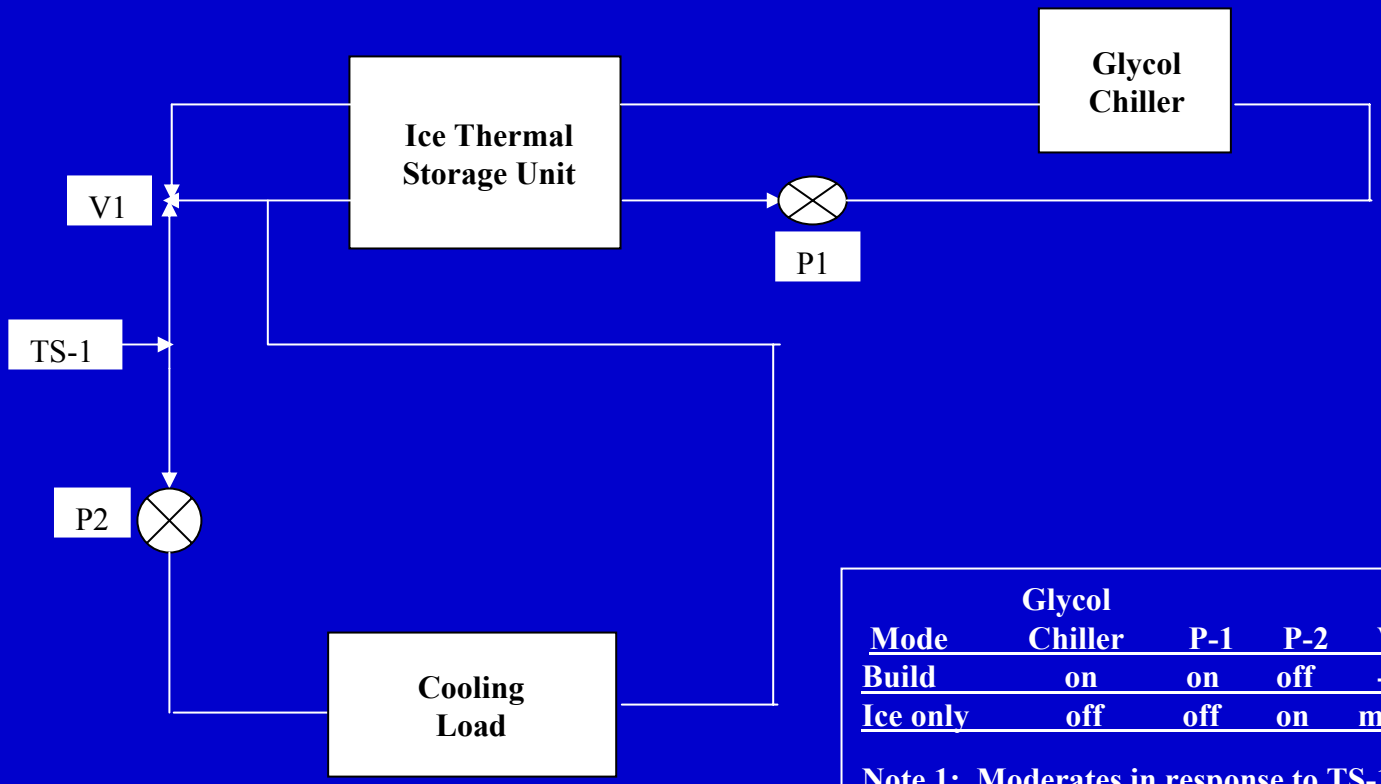
Task #3: Engineering Design & Cost Analysis

The work include a typical equipment arrangement for turbine inlet air-cooling operation using the ice thermal storage technology. Based on the engineering design, a preliminary cost analysis will be performed to evaluate the market viability of the proposed approach using the ice thermal storage cooling system.

Ice Thermal Storage System for Intake Air Cooling to Gas Turbine



Schematic of Ice Thermal Storage Unit



Mode	Glycol Chiller	P-1	P-2	V-1
Build	on	on	off	---
Ice only	off	off	on	mod.[1]

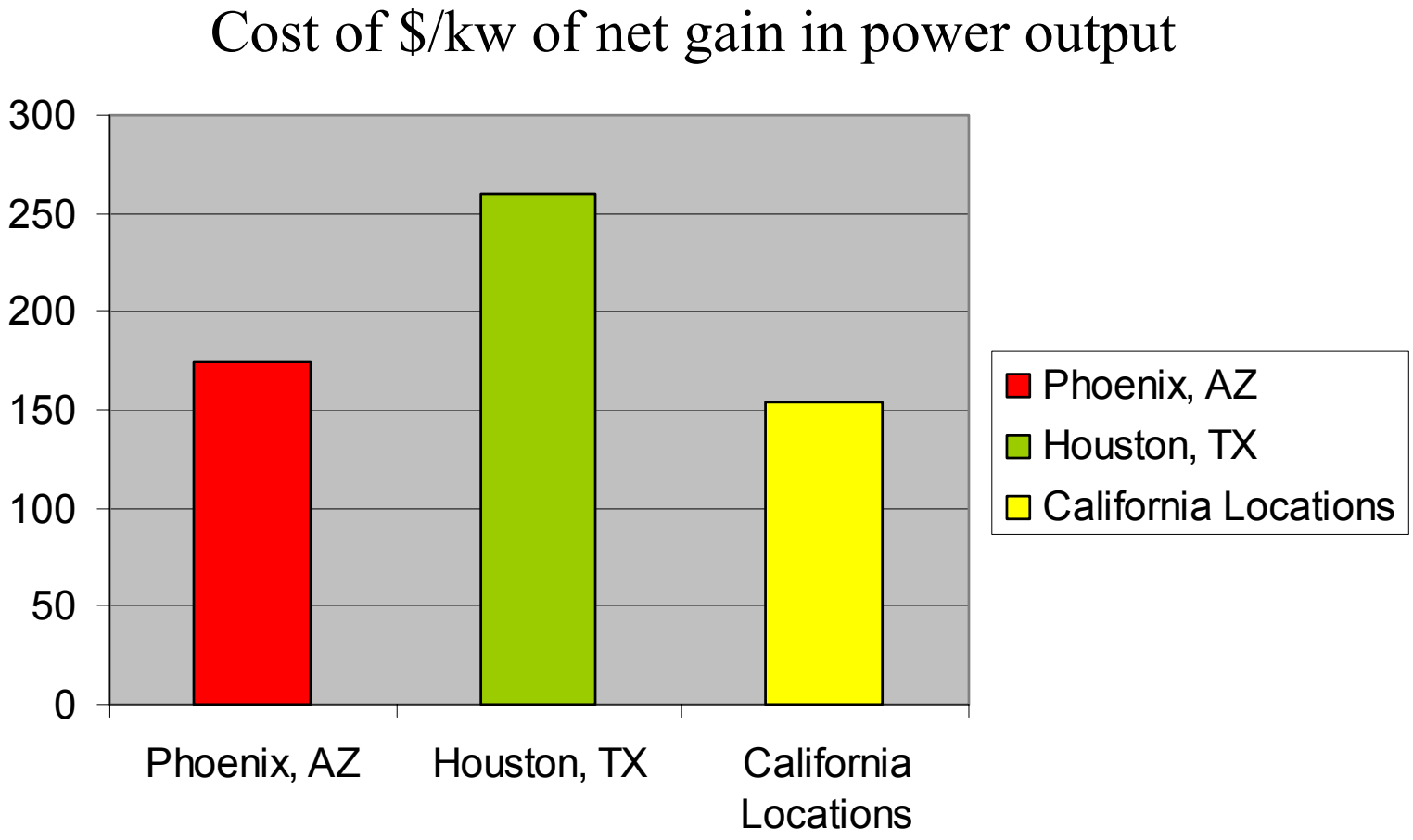
Note 1: Moderates in response to TS-1

Sample Cost Analysis (1)

Cost Base: $800/kw turbine and $200/kw Ice thermal Storage

Plant Concept	**Turbine Only**	**Turbine+Cooling**
Kw output@ 59 ^{0}F (IOS)	43,500	43,500
Kw output@ 102 ^{0}F Ambient	28,700	43,300
Plant investment, $\$10^6$	34.80	37.77
Income (power sale), $\$10^6$/yr	17.55	19.05
20-yr loan payment@ 12%, $\$10^6$/yr	4.18	4.53
Operating cost, $\$10^6$/yr	7.46	8.10
Net income, $\$10^6$/yr	5.91	6.42
Income difference, $\$10^6$/yr	--	**0.51**
Income difference for 20-yr loan, $\$10^6$	--	**10.20**

Sample Cost Analysis (2)



CONCLUSIONS

1. The use of ice thermal storage technology to cool the intake-air to the gas turbine is a cost effective means to increase its power output and reduce its heat rate. In addition, the cooled air releases its water that, in turn, can be collected and utilized.
2. The largest net gain in power output is in the arid hot climate and least in the coastal, humid regions.
3. A case study for a plant using a 50-megawatt gas turbine shows that a cost saving up to $500,000/yr can be realized when ice thermal cooling system is applied.
4. The amount of water recovery can be as much as 35 acre-ft/yr for a 50-Mw gas turbine operated with ice thermal cooling in Phoenix, AZ.

CONCLUSIONS

1. The use of ice thermal storage technology to cool the intake-air to the gas turbine is a cost effective means to increase its power output and reduce its heat rate. In addition, the cooled air releases its water that, in turn, can be collected and utilized.
2. The largest net gain in power output is in the arid hot climate while lesser in the coastal, humid area, and least in cooler northern regions.
3. A case study for a plant using a 50-megawatt gas turbine shows that a cost saving up to $500,000/yr can be realized when ice thermal cooling system is applied.
4. The amount of water recovery can be as much as 35 acre-ft/yr for a 50-Mw gas turbine operated with ice thermal cooling in Phoenix, AZ.

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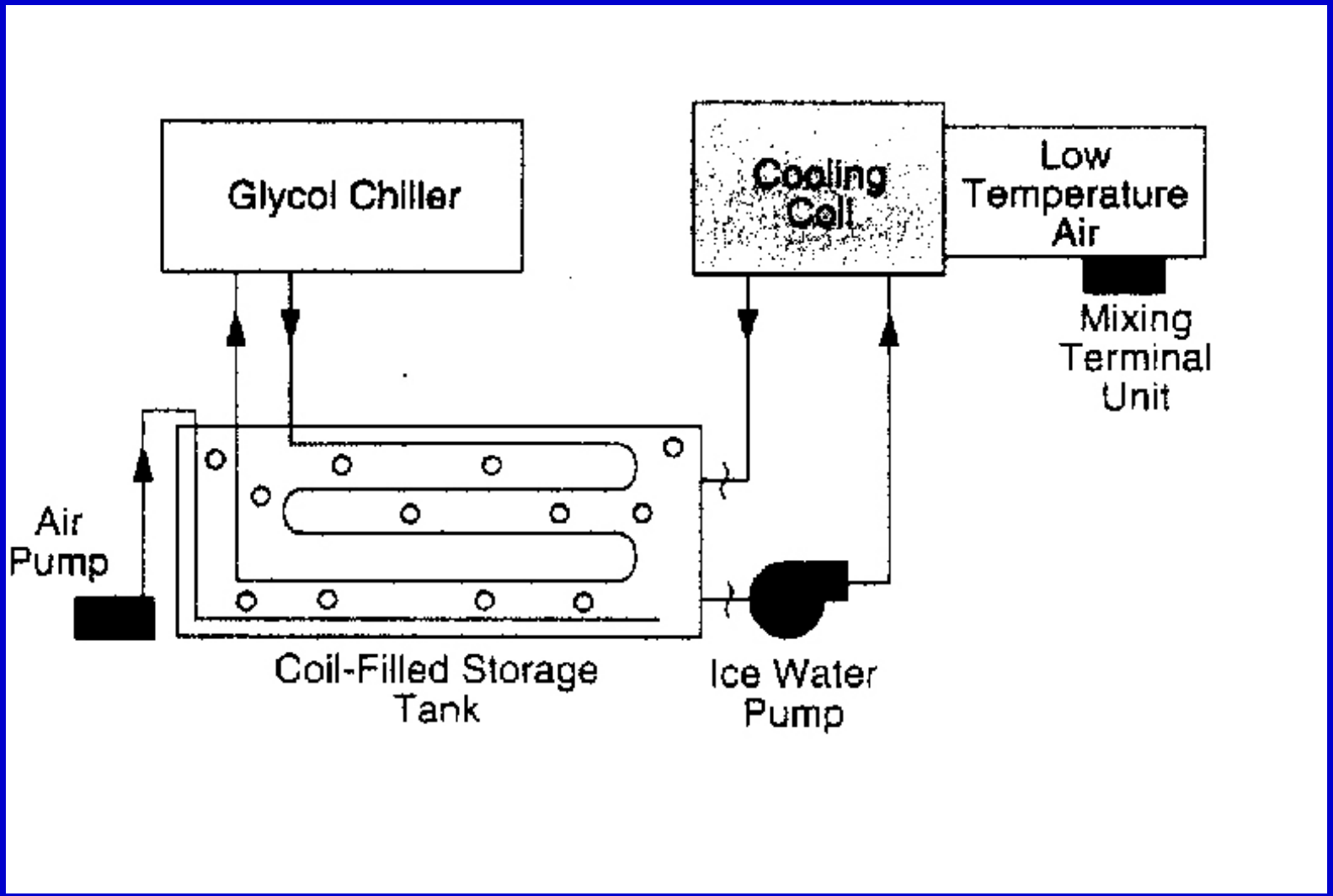
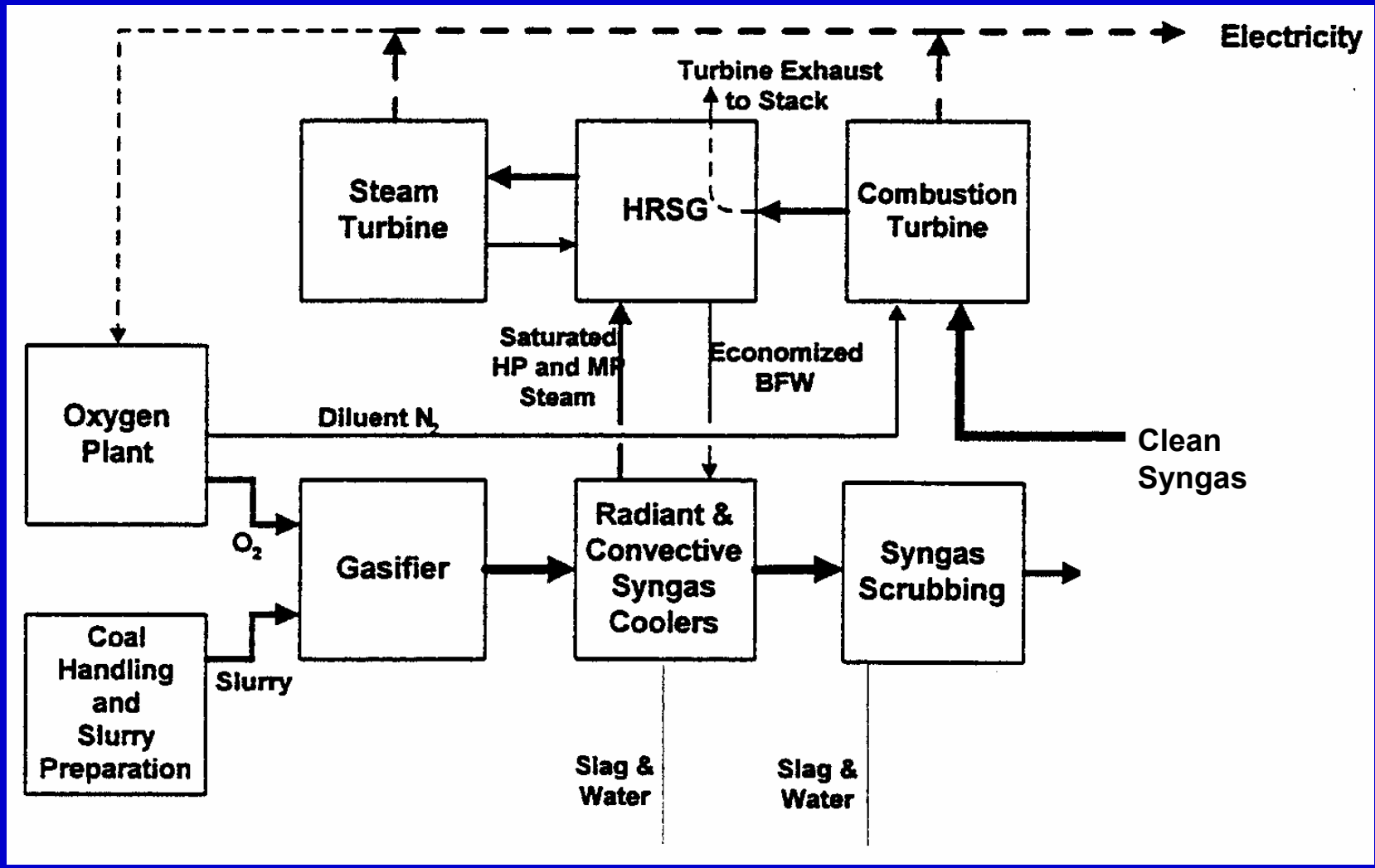
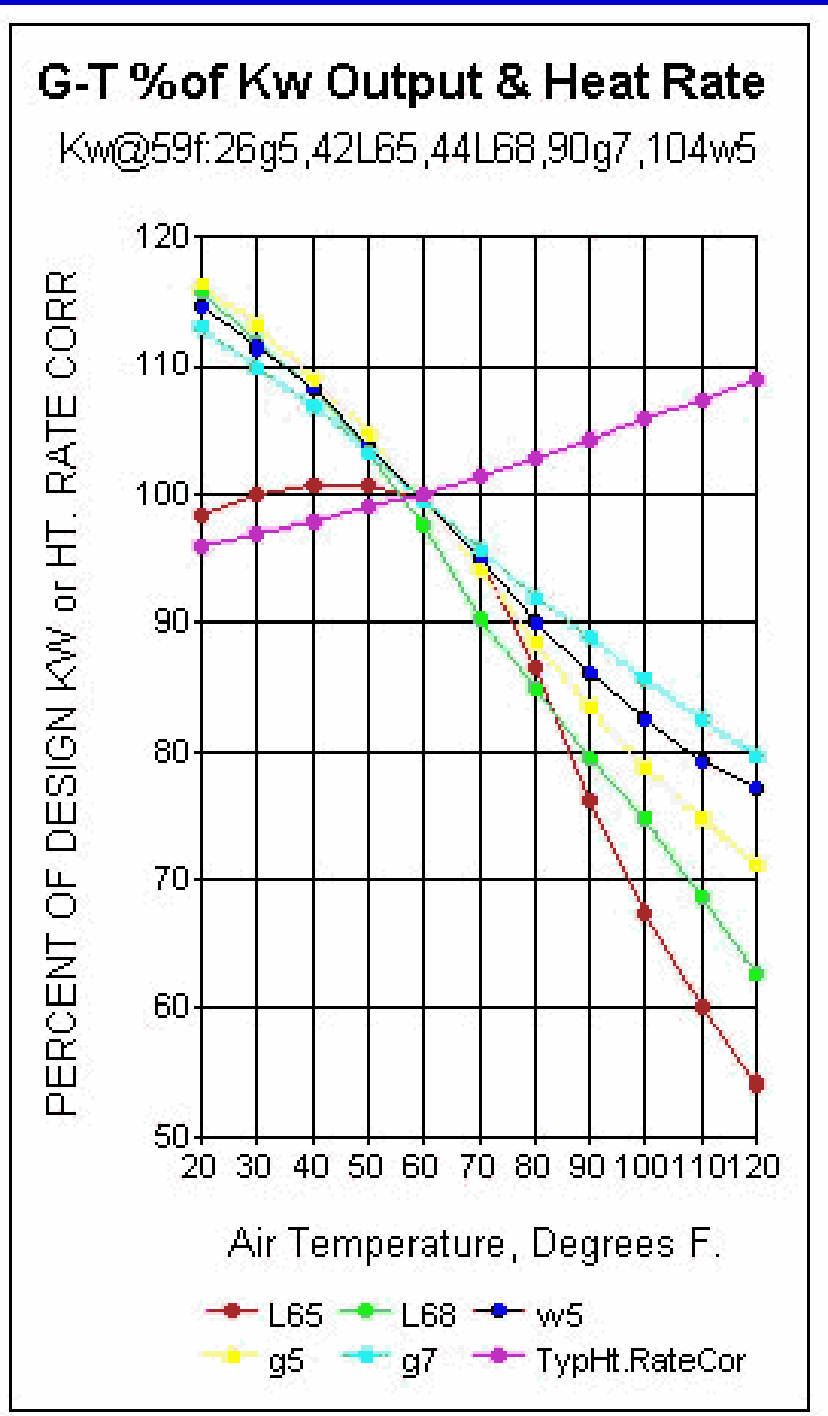


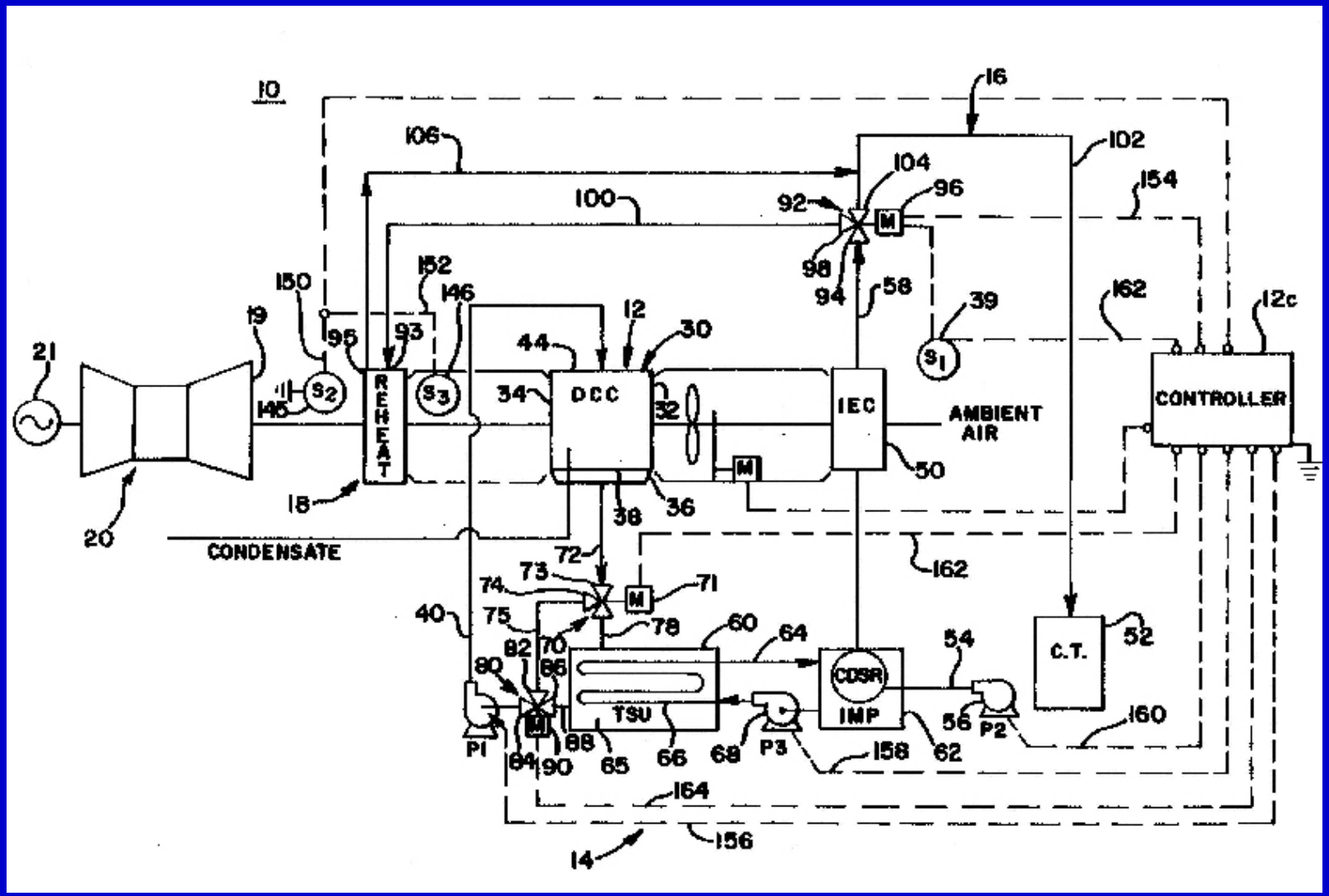
Schematic of Typical Integrated IGCC Power Plant



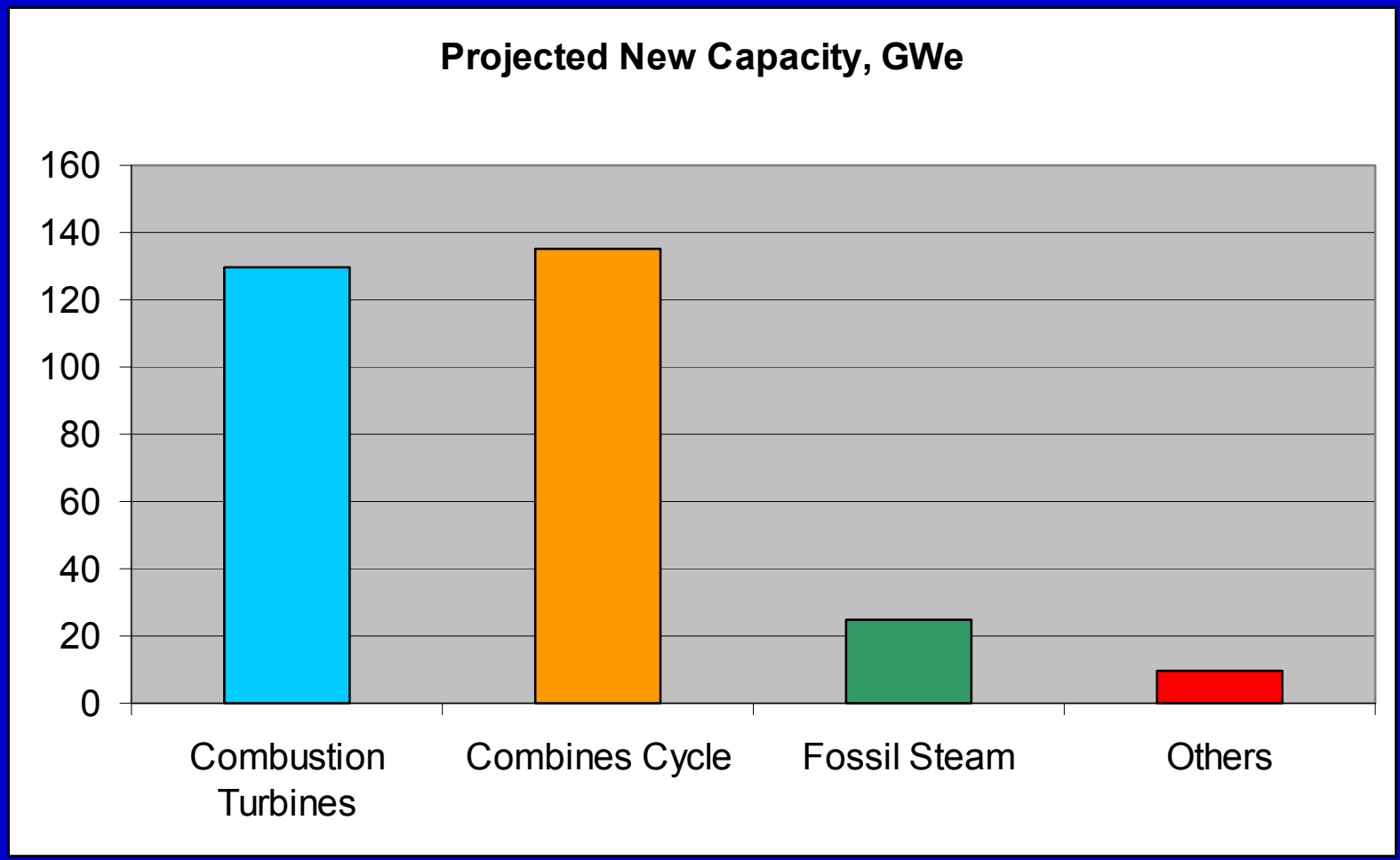
Typical Turbine Performance Curves



Equipment Arrangement for Ice Thermal Storage Cooling System



New Generation Capacity Forecast 1998 -2020

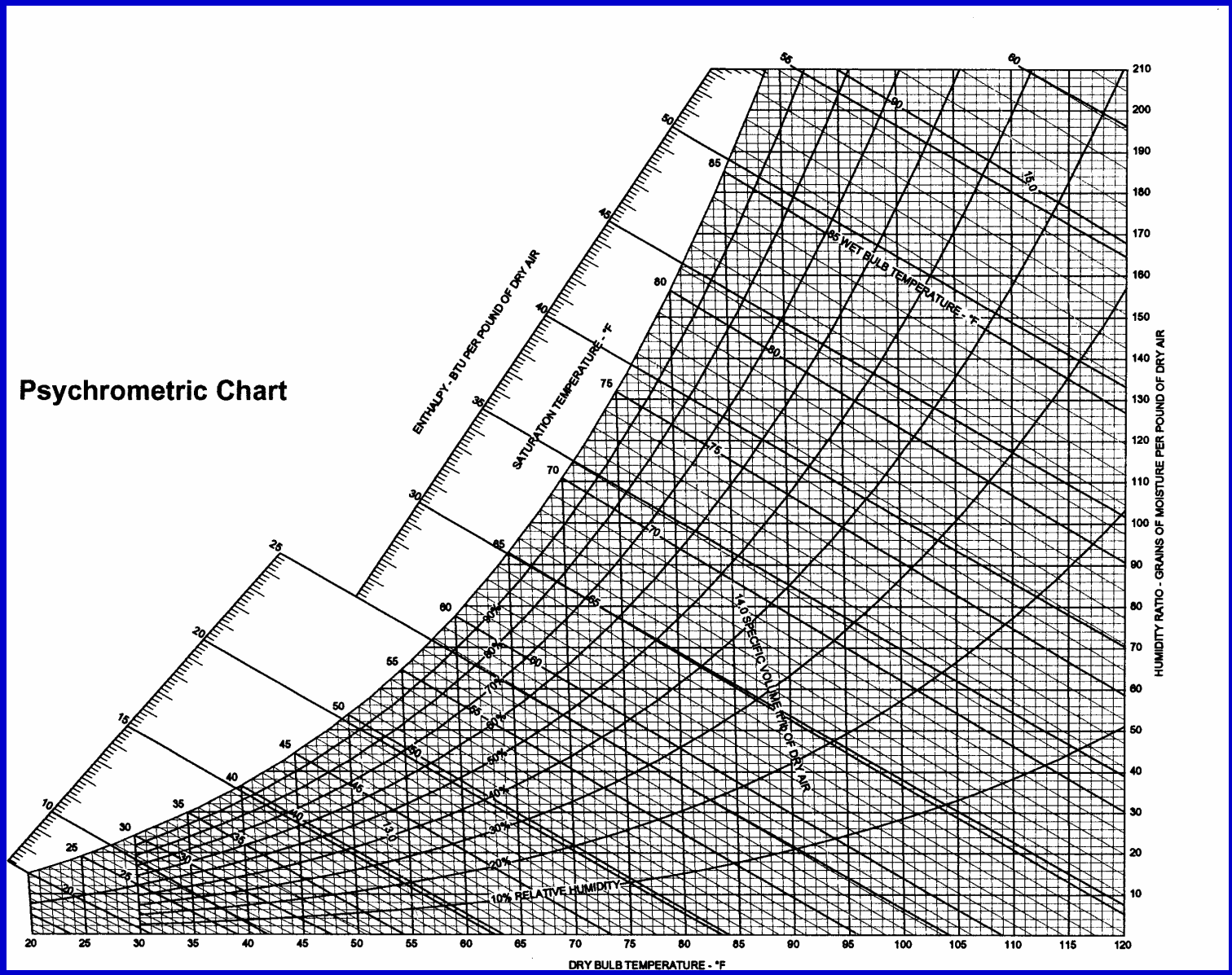


Sample Engineering Weather Data

Ellington Field Air Force Base / Houston Texas

(Latitude 29 37 N Longitude 95 10 W Elevation 40 feet)

July

Temperature Range D B, °F	Total Obsn	M C W B °F
100/104	0	80
95/99	18	79
90/94	106	78
85/89	142	77
80/84	153	76
75/79	250	74
70/74	68	70
65/69	5	65
60/64	1	59
<55/59	no data	no data

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